Remarks on Colour-Blindness and the Tests to be adopted for its Detection

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REMARKS ON COLOUR BLINDNESS AND THE TESTS TO BE ADOPTED FOR ITS DETECTION.

By F. W. Edridge-Green, M.D., F.R.C.S.

In the *Lancet* of May 26, 1900, I drew attention to the inefficiency of Holmgren's test for colour blindness, and the change which has taken place in medical opinion. So strong was the opinion ten years ago in favour of this test that a leading ophthalmic surgeon, when I stated that I had passed a colour blind man with Holmgren's test, replied that he was certain that I had made a mistake and "not having seen he could not believe."[1] It will be noticed that I have said "medical opinion," because I know of, at least, one physicist who firmly believes in this test. In bringing forward the additional evidence in support of the views which I have already published, I will commence with the Report of the Royal Society's Committee on colour vision. It will be obvious that if I can obtain evidence from this report in favour of my views, it will be doubly important as the Committee gave their verdict in favour of Holmgren's test. How they came to this opinion in face of the evidence before them is incredible to me, but I may say candidly that I do not consider a physicist a proper person to be a referee on this question, as he is always liable to mistake for psychical phenomena results which are only

[1] *Journal of the Society of Arts*, January 24, 1890, p. 204.

physical, chemical, or electrical. When the phenomena are psychical they cannot be measured by the balance and the rule, but must be gained by direct evidence from the mind itself. The physicist is also very liable to fall into the error of comparing facts which are not comparable. Of this I will give instances when dealing with the theories of colour perception.

In reading the Committee's Report, the last page of which gives a summary of the cases of colour blindness detected at the examination of about 300 railway employés, one is struck by two facts: first, that five colour blind persons escaped detection by the wool test, and secondly, *no colour blind person escaped detection by all the lantern tests.* That is to say, that though a colour blind person was passed by one lantern test, the same man was rejected by another examiner using another lantern test. The obvious conclusion is, therefore, that a lantern test could be constructed that would detect all cases. In this connection I may mention that I am incorrectly reported in two respects—first, I rejected No. 191 instead of passing him, and secondly, I detected nine colour blind men. I may mention that No. 191 was the most marked case of colour blindness that I examined. He confused purple and grey with green. We are, however, now only concerned with the facts before us, and they are quite sufficient for my purpose. The two cases which are recorded as rejected by me each present peculiar characters which made me make the notes recorded at the bottom of the page. It will be noticed that No. 122 was rejected by Holmgren's test but was passed by two examiners using lantern tests. This is precisely the class of colour blind who will escape detection by the ordinary lantern test. When I was appointed by the Board of Trade to advise on the subject of Colour Blindness, one of the first cases that was referred to me was of this kind. The second

case, No. 641, is even more important, as he was passed by Holmgren's test, and he is typical of the class of cases that are passed by this test.

The reader will not be surprised to hear, after reading the above, that the Holmgren test has in practice been found unsatisfactory. (See *Lancet*, May 26, 1900.)

I may say that in addition to the above I have numerous letters from specialists expressing the same views, but to these I cannot refer without asking the permission of the authors.

Before discussing present opinion on the theories of colour perception I will give my own views[1] in the briefest manner, as it will make the points that I wish to discuss more intelligible.

They are that the perception of colour is conveyed to the mind through a perceptive centre. That this perceptive centre is only able to distinguish six definite points of difference (colours) in the spectrum which really presents millions. We, therefore, for the normal sighted have a hexachromic theory of colour vision which is independent of light and shade. A hexachromic theory will obviously explain all that can be explained by a trichromic theory. It also agrees with the fact that both blue and violet have both been demonstrated to be primary. The degrees and varieties of colour blindness are perfectly explained by the theory. Assuming that the perceptive centre is smaller, fewer points of difference will be seen. The phenomena of contrast are explained on the view that colour being a point of difference, this becomes more marked on comparison. If we contrast a yellow with a greenish yellow, the yellow inclines to orange, and the greenish yellow to yellow green. This could not be explained by assuming that the colours differ

[1] "Colour Blindness and Colour Perception," *International Scientific Series*. Kegan Paul & Co.

by the addition of the complementary to each, as the complementary of yellow is blue, and this mixed with yellow would make white instead of orange yellow.

The theory I have formed as to the part played by the retina, which is supported by numerous experiments, is that light acting upon the retina liberates the visual purple from the rods and a photograph is formed, the cones conveying the impression of the photograph to the brain. I believe that shortening of the spectrum is due to some defect in this visual substance, as it may be met with in otherwise normal sighted persons and there is light as well as colour loss. When a colour blind person has his spectrum shortened the junctions of his colours are moved towards the unshortened side. In dichromic cases this has led to the division into red and green blindness. When the red end of the spectrum is shortened, the neutral point is proportionately nearer the violet end of the spectrum. I find that the position of the neutral point entirely depends upon the degree of shortening. When the spectrum is shortened in those who see three colours in the spectrum the junctions of the colours are nearer the unshortened side than in those who have a spectrum of normal length. A very strong fact against the Young-Helmholtz theory is that in so-called green blindness I have never found any loss in the perception of light similar to that found when there is shortening of the spectrum.

From the experiments that I have made during the last ten years, and from the evidence supplied by others, I feel convinced that not only is there a visual substance but that substance is purple. I will not refer to facts concerning the visual purple which are generally known, or to those which I have already mentioned in my book on colour blindness. Kühne, who made so many observations on the visual purple, stated that it could not be essential to vision, and

could not be the visual substance because it was absent from the cones, and only cones were to be found in the fovea centralis, the region of most distinct vision ; that it is entirely wanting in some animals which see very well ; and lastly, that animals such as frogs, naturally possessing the pigment, continue to see very well when their visual purple has been absolutely bleached, as it may be by prolonged exposure of the eyes to strong light. I will deal with the last two objections first. The second objection may be answered by the view that there may be a similar substance present in the eye of these animals having the same function, but that to our eyes it is colourless. The third objection may be answered by comparing the retina with any secreting gland. Just as the mamma keeps secreting on stimulation, the pigment cells of the retina may be secreting sufficient of the visual purple for vision, but not sufficient for external recognition. We know that when the retina is stimulated by light the processes of the pigment cells are forced down amongst the rods as far as the external limiting membrane. The first objection of Kühne is very important, but may be answered by the hypothesis which I have put forward, namely, that the cones are not sensitive to light but only to changes in the visual purple. I mean that they are not sensitive to light in the sense that they do not, when light falls upon them, convey any light sensation to the brain. They are sensitive to light in one way, namely, that when light falls upon them it causes the inner limbs to contract, but this change has been noted when light falls on the other eye or on the skin. This may be the means by which the visual purple is drawn out, and support is lent to this view by the fact that the following experiments can be best made with only one eye, and when no light is allowed to fall on any part of the body with the exception of

that which falls on the fovea centralis. They show that light may fall on the fovea centralis without producing any sensation.

(1) If we look at two small isolated stars of equal magnitude either may be made to disappear by looking fixedly at it, whilst the other remains conspicuously visible. I find that the phenomenon is most marked on a dark night, and when the star looked at is in a portion of the sky comparatively free from other stars, and when only one eye is used. On a very dark night a considerable number of small stars, occupying the centre of the field of vision, may be made to disappear, whilst stars occupying other areas of the field of vision are plainly visible.

(2) Other lights or objects, when small and with dark surroundings, as, for instance, a piece of white cardboard on black velvet, may be made to disappear in a similar manner.

(3) No change can be observed if a very bright light, a group of stars, or a uniformly illuminated surface, be made the subject of the experiment.

(4) If we look at an illuminated object through a pin hole in a piece of black cardboard, surrounded by black velvet, we find that unless it be very bright it will not be visible at all. On moving the eye, so that the image does not fall on the centre of the retina, the object appears brighter.

(5) In this experiment I made quite a bright lantern light disappear. I took the greatest care that no light entered my eye other than that falling on the fovea centralis, and the light faded at once and left the field of vision absolutely dark.

I find that the after image of any spectral colour, and of white light, is purple if we take care not to look at the colour too long. The following is an easy method of proving this. Look at a dull white cloud for a second or two and then close the eyes, covering

them with the hands so that no light can enter the eyes through the eyelids. A dull purple will first be seen, and for a few seconds this gets brighter and brighter, giving the sensation of a bright purple light. This gradually fades away from without inwards without changing colour. Mr. Shelford Bidwell has also made some very interesting experiments bearing on this point. Space will not permit me to do more than allude to other facts supporting this view of the functions of the rods and cones. They are — entoptic phenomena, anatomical distribution, area of greatest luminosity, and the fact that purple is the only colour not found in the spectrum.

In reviewing the theories of colour blindness, I will first draw attention to a most admirable paper by Dr. Pole, who has done so much to advance our knowledge of colour blindness. In this[1] and associated articles he points out the change of opinion which has taken place and the abandonment by Helmholtz of the older explanation of colour blindness. Professor Hamilton, in his exhaustive treatise on Pathology,[2] says when commenting on my theory: "The two theories of colour vision which for long held the field, and still, to a certain extent, retain it, were respectively those of Young and Helmholtz, and of Hering." He then describes these theories and says, "All these theories, however, pre-suppose that the essential defect is in the retina. From what we now know of the visual centre in the brain, it seems quite as likely, if not more so, that the vice is located in the apperceptive centre— that, in fact, colour blindness is essentially a disease of

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[1] "On the Present State of Knowledge and Opinion in Regard to Colour Blindness," by W. Pole, F.R.S., *Transactions of the Royal Society of Edinburgh*, 1893.

[2] "A Text Book of Pathology," by D. J. Hamilton, M.B., F.R.C.S.E., F.R.S.E. London: Macmillan & Co., vol. ii., p. 699.

interpretation, not one which is bound up with the mechanism placing the visual centre in communication with the periphery; that it is, in fact, simply a form, and probably a very pure one, of congenital psychical blindness."

I will not go through the objections which I have raised to any retinal theory of colour vision, because these objections have never been answered; they have either been accepted or ignored. I may say that I totally disagree with the opinion that normal colour vision is trichromic, and I consider that the curves and equations which have been constructed to prove that normal colour vision is trichromic are mathematically incorrect, judged only by the facts on which they were based. I raised this point in a paper which was read before the Royal Society on June 21 of this year. Equal stimulation of the three sets of fibres is supposed to cause the sensation of white light. Red and green when mixed make yellow. Violet and green when mixed make blue. But yellow and blue when mixed make white, which makes one portion of green too many, thus: R + G = Y, and G + V = B, but Y + B = white, therefore, R + G + G + V should equal white, but R + G + V = white.

Opinion has steadily grown in favour of the view that a central lesion may be the cause of colour blindness. In 1897 the following was written by Dr. R. Hilbert:[1] "Only a single author considers the existence of a colour perceiving centre as unnecessary."

In a discussion on some cases of colour blindness before the Heidelberg Ophth. Soc., 1898,[2] "Lucanus mentioned a case of total colour blindness which recovered completely and which he considered to have been of central origin. Leber observed that there is

[1] Richard Hilbert, *Die Pathologie des Farbensinnes*, 1897.

[2] Ophthalmic Review, 1899.

a good deal to be said in favour of the view that the congenital colour blindness, too, is due to a central lesion."

Lastly, the case recently recorded by Dr. Mackay[1] is of great importance as evidence of the exact position of the colour-perceiving centre in the brain.

In another paper[2] I have discussed the limitation of physical methods in the investigation of the phenomena of sight. If my view be correct as to the existence of a separate colour-perceiving centre, then methods which aim at obtaining information concerning a colour by measuring its luminosity are as likely to be followed by a useful result as if we were to endeavour to obtain information concerning the pitch of a note by observations on the intensity with which it is struck.

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[1] Ophthalmic Review, 1900.
[2] *Lancet*, August 4, 1900.